Understanding the Foraging Ecology of Beaked and Short-Finned Pilot Whales in Hawaiian Waters

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LONG-TERM GOALS

The overall goal of our research is to understand beaked whale foraging and to learn how to alleviate acoustic encounters between Navy assets and beaked whales and other deep diving odontocetes. Understanding of the characteristics and dynamics of the prey field is critical in understanding the foraging behavior and life cycle of beaked whales. The movement patterns of any animals are strongly affected by the availability of food resources, so in order to understand the foraging behavior of beaked whales, the behavior of the prey, the oceanographic conditions affecting the presence of the prey and how the whales interact with the prey field all needs to be better understood.

OBJECTIVES

1. Obtain a preliminary understanding of the biomass environment in which beaked whales and other deep diving odontocetes are foraging by collecting preliminary data with EK-60 scientific echosounder at 38 and 70 kHz
2. Collect PAM data to determine pattern of foraging for beaked whales and other deep diving odontocetes in the Kona coast line
3. Demonstrate the utility of the DIDSON high-resolution sonar in obtaining biomass images at depth commensurate with typical foraging depth of deep diving odontocetes

APPROACH

Beaked whale research in Hawaii has been conducted mainly in the Kona coast of the island of Hawaii and there are an abundance of beaked whales along this coast line (Baird et al., 2006). The mountains of Mauna Kea and Mauna Loa are instrumental in providing a lee so that this area is usually very calm and easy to work in. Funds were not received until January, 2012 and a no-cost extension until August, 2013 was approved to accommodate a "piggy back" participation with a NOAA cruise of the Kona coast in June, 2013. Further funding was not granted until the last quarter of 2014. However the project was barely able to limp along by finding other funding sources for two graduate students and by generosity of the Schmidt Oceanographic Institute who provided 5 days for ship time for further work on the Kona Coast, in March 2014. Differences in variables such as the characteristics, dynamics, density, diurnal variations of the prey field and how they relate to the presence of beaked whales will be examined. We used three main techniques and tools to determine the distribution and abundance of the prey field of beaked whales, to understand the relationship of beaked whales and the prey field and to understand how beaked whales interact with the prey field. The three tools used in this study and the manner in which they are used and the type of data they collect are enumerated below.

1. The first tool are three of EARs (operating at 80 kHz sample rate) that were deployed in the study area at depths of 1 km. The EAR data will provide a good indication of the diurnal foraging pattern in each area and also indicate which of these areas beaked whales tend to frequent the most. The EARs will be used during the entire study.
2. The 38 and 70 kHz versions of the Simrad EK-60 scientific echosounder will provide across slope and along slope examination of the prey field. The acoustic volume scattering along the survey tracks will be determined and related to density estimate obtained with the profiler discussed in the next paragraph. We will start of with rectangular transects with long legs nearly parallel to shore and in water depths between 700 and 1500 m. Isobaths in the Kona coast of the Big Island tend to follow the shape of the shore line.

The third tool will be a specially fabricated profiler to investigate the composition, density and the characteristics of the micronekton in the deep layers that beaked whales forage on. The key instrument of the profiler will be the DIDSON high resolution imaging sonar and a low- light video camera system.

The research during the first year geared towards obtaining basic information on the environment that the deep diving odontocetes are foraging in. To this end, the various tools were used almost independently. Having obtained some basic but important information, the project will begin to use the various tools in a more integrated manner. Three stations will be marked off along the Kona coast based on information obtain from the passive acoustic monitoring work done with the EARs. Before each survey field trip, an EAR will be deployed at each station. EK-60 active acoustic surveys will be conducted in the near vicinity of each EAR while visual observers will scan the water for beaked whales, short-finned pilot whales and sperm whales. The DIDSONprofiler will be used to sample the prey field at each station. If marine mammal observers detect whale species of interest, the survey will be terminated and a focal following approach will be taken to survey the scattering layers in the vicinity while the whales are both foraging and not foraging. The DIDSON profiler will be used at appropriate intervals during the focal following process. At the end of the field trip, all the EARs will be retrieved and the data obtained will be coordinated with both the EK-60 and DIDSON data.

The DIDSON profiler will be redesigned so that a low light video camera along with two LED array emitting light in the red spectrum will be used. The profiler will be redesigned for easier use with a small vessel rather than a large ocean going ship.

WORK COMPLETED

We have completed the analysis of the DIDSON data collected in three cruise off the Kona coast and have a draft ms ready for submission to a scientific journal. DIDSON data were collected over three cruises along the Kona coast of the island of Hawaii. The three cruises were: (1) NOAA Integrated Ecosystem Assessment 2013 cruise in June 2013; (2) NOAA Integrated Ecosystem Assessment 2014 in March 2014 and (3) University of Hawaii/Schmidt Ocean Institute Kona14 (UH/SOI KONA14) cruise in February 2014. During all the cruises DIDSON samples were collected at selected stations (Figure 1).

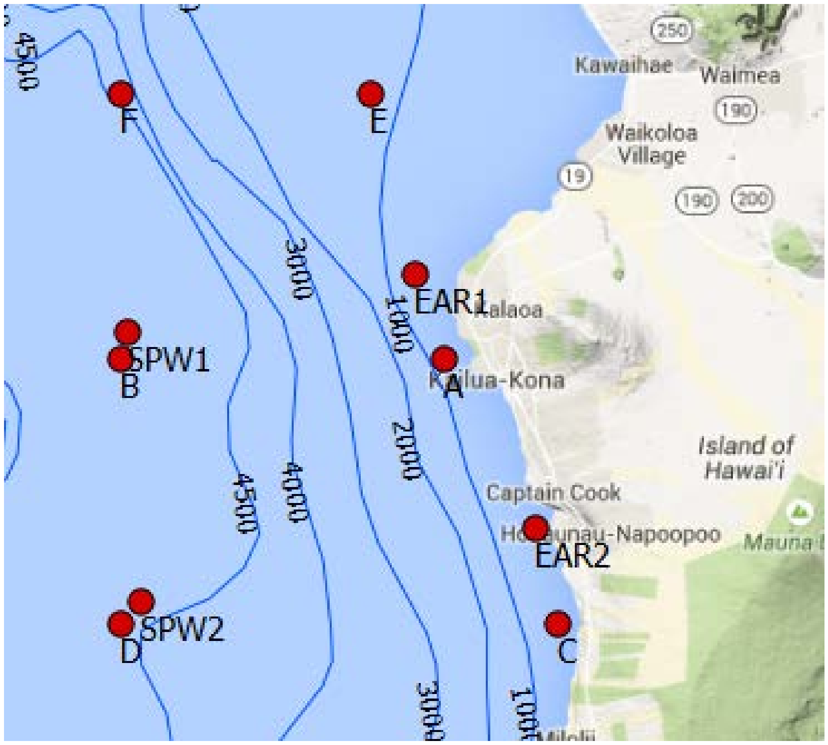

Figure 1 DIDSON sampling stations (dots) along the Kona coast of the island of Hawaii.

An EK60 38 kHz echosounder was used to locate the depth of DSLs and, using a CTD wire, the DIDSON was lowered in the water column below the DSL, and in the DSL for a standardize amount of time of 20 minutes at each depth sampled. Sometimes 2 different DSLs were present, and in this case, the DIDSON was used to sample both DSLs, and below the deeper DSL. Using a CTD wire allowed an accurate measure of the depth of the DIDOSN in the water column. The DIDSON was powered by a 30 volts custom made battery pack enclosed in a metal container, and data were stored to an internal memory. Due to the extreme depths of operation, the sonar was turned on before being deployed, turned off at the end of the operations, and no communication with the sonar was possible during the operation. The DIDSON acquires near video acoustic images in a fan-shape pattern across a 29° horizontal and 14° vertical area. For our study, it was set up to operate at a frequency of 1.8 MHz, which resulted in a sector divided horizontally into 96 separate $0{\cdot}3^{\circ} \times 14^{\circ}$ beams, acquiring 8 frames of data per seconds. Data were collected in a volume of water of 60.85 m^3, resulting in a 9 m operational range starting at 2 m from the sonar sound source. Figure 2 shows an EK60 38 kHz echogram, in which DSLs are represented by the dark horizontal layers, and the DIDSON is visible as a single horizontal line. As the picture shows, the DIDSON was lowered below the layers and data were acquired for 20 minutes; then the DIDSON was lifted up into the DSL and kept there for another 20 minutes.

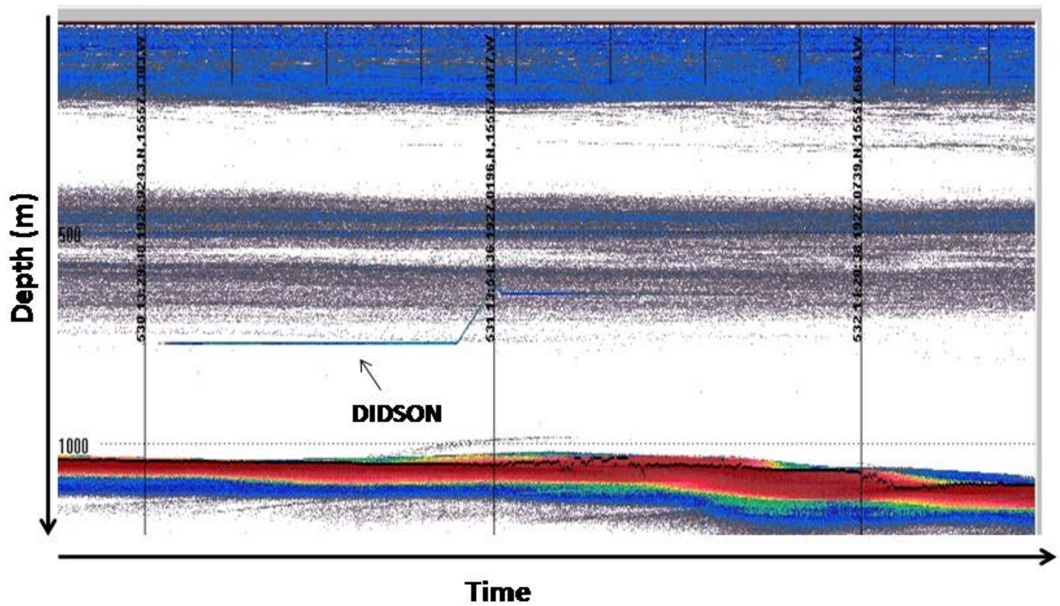

Figure 2 EK60 38 kHz echogram showing the DIDSON sampling routine. DSLs are represented by the dark horizontal layers, and the DIDSON is visible as a single horizontal line. The DIDSON was lowered below the layers and data were acquired for 20 minutes; then the DIDSON was lifted up into the DSL and kept there for another 20 minutes.

The "shallow" DSL ranged in depths between 360 and 580m. The "deep" DSL was found between 570 and 690 m, and the depth of the "below" layer sampling varied between 650 and 800 m. Maximum density recorded was 6.5 animals/ m^3. Density data show evidence of diel vertical migrations. Densities at night are lower than at day-time at the sampled depths. Animals as small as 5 cm were detected, and the biggest animal was 3 m long, likely a squid (Figure 3).

At each depth and station, the size frequency distribution of animals was calculated (Figure 4 shows an example), and the peak of the distribution was used in the mixed model, as well as the density and the number of animal bigger than 50 cm. As one can expect, the distribution shows greater abundance at smaller sizes. The most abundant animals are in the range of 20 - 30 cm, in this case. This category might consist of secondary consumers. Larger consumers, ranging between 100 and 150 cm, are less abundant.

RESULTS

We are in the process of relating volume backscatter data obtained with the 38 kHz EK-60 with complementary data obtained with the DIDSON

A five day cruise was conducted off the Kona coast of the Hawaii Island incorporating a low-light ROV Navigator II camera to the DIDSON frame in February. Illumination was provided by an array of red LED. Unfortunately, an equipment malfunction occurred so that the cruise was terminator after 3 days. We are in the process of repairing the malfunction and damage to the equipment.

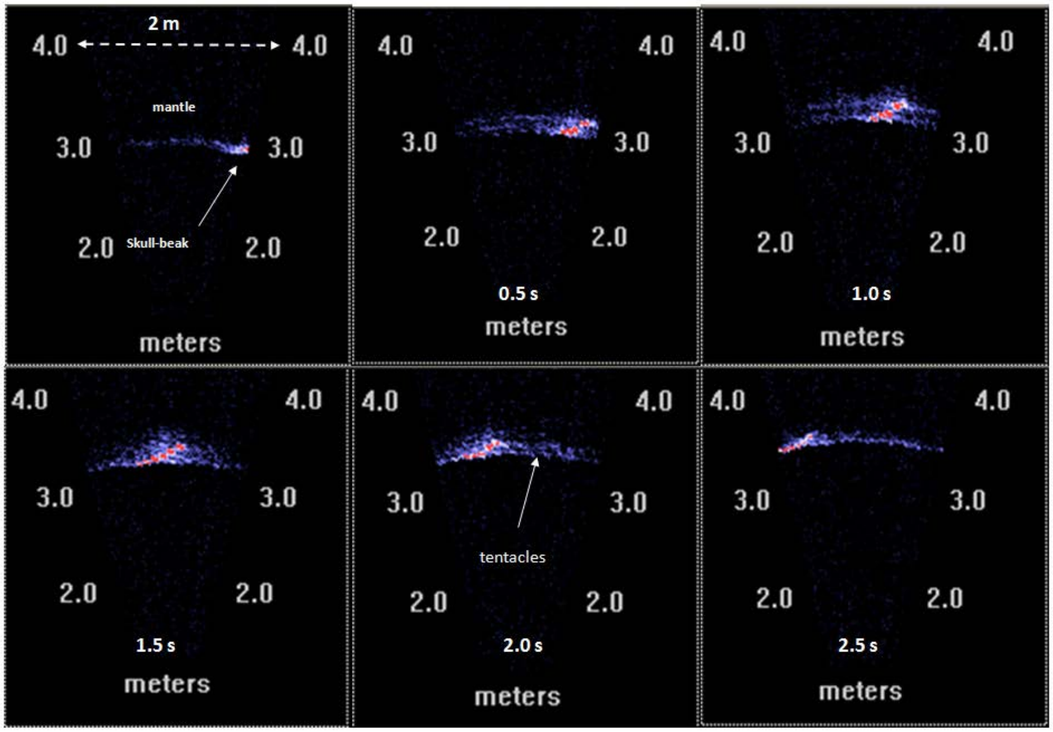

Figure 3: Sequence of frames from the DIDSON taken at station E in which a 3 m long squid was detected by the DIDSON. The red colored part represent high backscattered sound from the head-beak, while the softer tissues, mantle and tentacles, return lower sound intensity and they appear blue.

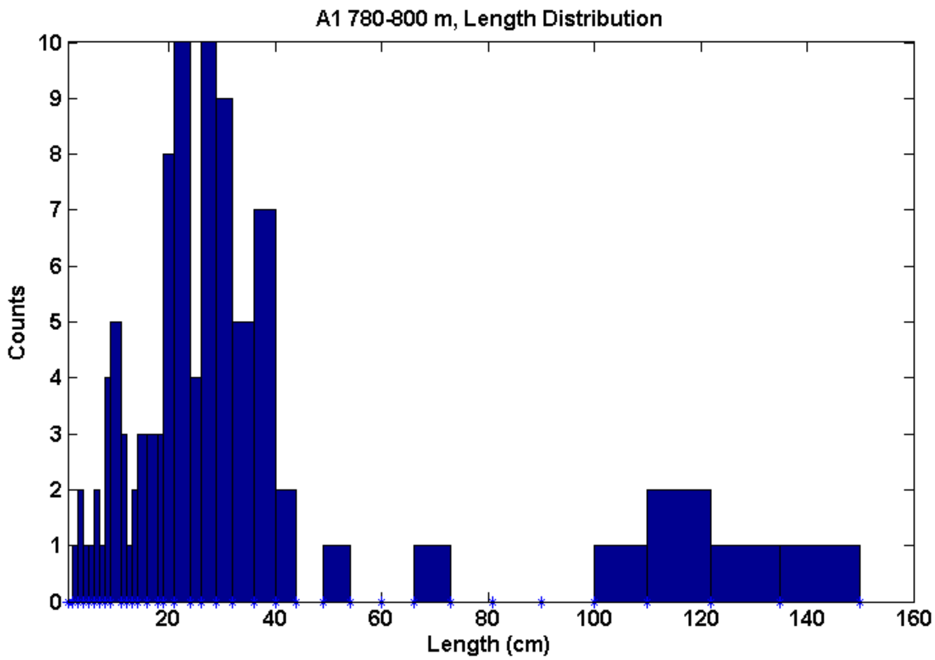

Figure 4: Size frequency distribution at station A during the NOAA IEA13 cruise.

IMPACT/APPLICATIONS

A general understanding of the environment that beaked whales and other deep-diving odontocetes are foraging in is progressively being developed as data from the EARs, Ek-60 echosounders and the DIDSON are being analyzed. There seem to be a deep layer present at about 400 – 500 m deep which exhibit very little vertical migration on a diunal scale. Animal density was higher in June 2013, during the NOAA IEA 2013 cruise, than during the other two cruises, and this was soon after the peak in intensity of a cold core eddy which had formed west of Hawaii island. Interestingly, the peak of the length distribution and the number of potential predators (animals bigger than 50 cm) also were higher in June 2013. The marine ecosystem of the leeward side of the island of Hawaii is profoundly influenced by cyclonic eddies. Cold core eddies are known to enhance productivity and can increase vertical carbon export, but not in all cases. Higher trophic levels are also influenced by cyclonic eddies, which can affect the distribution of pelagic fish and melon headed whales (*Peponocephala electra*). Also there is some trawl data suggesting possible increases in micronekton density at depth in response to cyclonic eddies. Whether the cyclonic eddy is truly the cause of higher animal densities in June 2013 in the DSLs is unclear because we lack data from prior to the eddy formation. Regardless of the cause, not only the density of animals was higher than in other periods, but also the size and abundance of higher trophic level animals. If the community changes were driven by eddy activity then surely for the larger size classes with generation times exceeding several months, the increase in their density would be from aggregative processes, likely due to their attraction to zooplankton food resources which are known to increase in cyclonic eddies.

The density of organisms between the bottom part of the deep layer and the bottom is relatively low. Our best understanding is that the prey of beaked whales, mainly squids, can generally be found in this depth regime. The squid probably feed on the bottom portion of the deep layer and deep diving odontocetes typically dive to depth beyond the deep layer to forage. One possible reason for this type of behavior is that the organisms of the deep mesopelagic layer can represent unwanted reverberations for echolocating animals making it more difficult to perform biosonar detection, classification and tracking of prey. Therefore, the density and health of the deep scattering layer is an important entity in the foraging behavior of deep diving odontocetes since the prey of these whales will be affected by the state of the deep mesopelagic layer.

An important insight obtained during this feasibility phase of this research is the connection between DIDSON and EK-60 data. Fine estimates of the density of organisms in the mesopelagic layer can be obtained with the DIDSON and this data can be used to “calibrate” biomass estimates of EK-60 soundings. Taking this approach will allow for obtaining better esimate of density of mesopelagic organism in the deep layer by EK-60 echosounding surveys.   This in turn may provide information of the likelihood of deep diving odontocetes foraging in a particular area of the ocean.

The most important results from this feasibility phase is that the three different type of sensors used in this project can provide the most advanced information that will eventually lead to a much better understanding of the foraging behvior of beaked whales and also other deep-diving odontocetes.

RELATED PROJECTS

None